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To: Mr. H. G. Daniel Date: December 30, 1974

From: J. E. Tindall

Subject: Tar Monitoring Computer Program

A computer program has been prepared which can provide weekly statistical analyses of Quality Control tar data quickly and easily. These analyses will respond to certain kinds of changes in tar deliveries faster than analyses based on four-week running averages, and they will be more likely to detect certain kinds of changes in tar deliveries than can be done by looking at a single tar value or a running average of tar values for one size or packing of one brand at one location.

Manufacturing Center computing personnel are adapting the program to the Q.C. System 7 computer. Until that work is done and Manufacturing Center personnel begin operating the program on a routine basis, it is suggested that a weekly report be issued to Q.C. from R&D. This would give Q.C. personnel an opportunity to familiarize themselves with the program output and to make suggestions for additional or modified analyses.

The first section of this report describes the data which will be used by the program and the preparation of that data, the second section describes two preliminary analyses results of which are essential to the main analyses, the third section describes the main output of the program, and the last section covers areas in which some flexibility can be exercised with no additional programming.

I. DATA AND PREPARATION

The tar monitoring program will use virtually all of the weekly tar data collected by Manufacturing Center Q.C. and its analyses will always be based on the most recent thirteen weeks (one quarter) of this data. Each week Q.C. measures the tar of sixteen sets of cigarettes. Each set consists of one or more Philip Morris production cigarettes (usually one size of one brand from several locations), a comparable competitive brand, and a Monitor. These sets change slightly as production shifts from one location to another and as brands are added or deleted, but Table 1 shows approximately what they are at the present time.

Preparation of the data for processing will require two steps each week:

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Table 1: SETS OF TAR MEASUREMENTS (CIGARETTES MEASURED TOGETHER)

Set 1	Brand	Monitor	Philip Morris	Lucky Strike			
	Version	16	70 - S.S.	NF 70			
Set 2	Brand	Monitor	Commander	Pall Mall			
	Version	16	S.S.	NF			
Set 3	Brand	Monitor	Virginia Slim	Silva Thin			
	Version	16					
Set 4	Brand	Monitor	Marlboro	Marlboro	Marlboro	Marlboro	Winston
	Version	16	100 box S.S.	100 S.S.	100 M.C.	100 Lvlle.	100
Set 5	Brand	Monitor	Parliament	B&H	Kent		
	Version	16	85 - 20th	85 - S.S.	85		
Set 6	Brand	Monitor	Parliament	Kent			
	Version	16	80 - S.S.	80			
Set 7	Brand	Monitor	Parliament	Tareyton			
	Version	16	100 - S.S.	100			
Set 8	Brand	Monitor	Marlboro	Marlboro	Marlboro	Winston	
	Version	16	80 - S.S.	80 - M.C.	80 Lvlle.	80	
Set 9	Brand	Monitor	Marlboro	Marlboro	Marlboro	Winston	
	Version	16	85 - S.S.	85 - M.C.	85 Lvlle.	85	
Set 10	Brand	Monitor	Marlboro	Winston			
	Version	16	Light Lvlle.	Light Lvlle.			
Set 11	Brand	Monitor	B&H	B&H	B&H	B&H	Pall Mall
	Version	16	100 S.S.	100 20th	100 M.C.	100 Lvlle.	100
Set 12	Brand	Monitor	Multifilter	Galaxy	Lark	Tareyton	
	Version	16	Lvlle.	Lvlle.	85	85	
Set 13	Brand	Monitor	Marlboro	Kool			
	Version	16	Menthol S.S.	85			
Set 14	Brand	Monitor	Alpine	Multifilter	Salem		
	Version	16	S.S.	Menthol Lvlle.	85		
Set 15	Brand	Monitor	B&H	Pall Mall	Salem		
	Version	16	Menthol Lvlle.	Menthol 100	100		
Set 16	Brand	Monitor	Virginia Slim	Silva Thin			
	Version	16	Menthol	Menthol			

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A. The tar values must be copied from the weekly tar notebook in a format which is basically as shown in Table 1: one set of tar values per row preceeded by the date for the end of the week's production. This will require about ten minutes.

B. The tar values must be punched on sixteen cards, one card per set, in the same order as above and with a specific numerical format. This will require about five minutes.

The program is general enough so that changes in the sets of cigarettes which are measured together can be accommodated by changing control cards. No new programming should be necessary.

II. PRELIMINARY ANALYSES

The tar monitoring program is designed to analyze, each week, the last thirteen weeks of Manufacturing Center Q.C. tar data for groups of brands (or versions of a brand) with some common characteristic. Some possible groups include all Marlboros (considering size, packing, and manufacturing location) with the same formula, all brands with the same target tar, all brands made at one location, and all brands made by one company. The analysis for any one such grouping of brands is one section of the main output of the program and will be discussed in Section III. Before these main analyses, the program performs two preliminary analyses.

The print-out for any one week will start with a section labeled "FTC Tar Analytical Correlation," the first preliminary analysis. This will be followed by a section labeled, "Analysis of Monitor Tar," the second preliminary analysis.

A. Correlation Analysis

Since all Monitors come from one source, there should be no weekly fluctuations in Monitor tar beyond those within one week. In particular, Monitor tar should not fluctuate from week to week in a manner similar to any production cigarette measured with it. A correlation between Monitor and a cigarette measured with it is an indication that something in the analytical process itself is changing from week to week. It might be temperature and humidity conditions, changes in smoking machines, changes in materials used in the analytical measurements, etc.

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The program calculates correlations between Monitors and the cigarettes measured with the Monitors in the same set over the last thirteen weeks. There will be approximately forty-six such correlations.

Under "FTC Tar Analytical Correlations" the program prints out the number of such correlations, the average of the correlations, the standard deviation of the correlations, and the t-value corresponding to a test of the hypothesis that the average correlation is equal to zero.

In the data examined thus far, the correlation has been significantly greater than zero. A positive correlation is not cause for alarm. However, it is an indication that the variation in tar measurements could be reduced thus increasing the chance of finding changes in tar when they occur.

B. Analysis of Variance for Monitor

Two reasonable hypotheses concerning Monitor are as follows:

1. There are no differences in Monitor from week to week (if the series has not changed).

2. There are no differences in Monitor from one set of measurements to another.

Each week a two-way classification analysis of variance is performed on the Monitor tar values - thirteen weeks and sixteen Monitors per week (one for each set of cigarettes).

Besides the tests of the two hypotheses above (to be discussed in Section III), the analysis of variance provides estimates of three quantities:

1. Error Variation - The variation from one Monitor to another plus the random variation introduced by the analytical process. This number, from week to week, will give an indication of how well the analytical process is being carried out.

2. Week-to-Week Variation (σ_W^2) - We can't expect any other cigarette to be more consistent from week to week than Monitor. This variation will be used in the main analyses as a standard against which to compare week-to-week variations in other cigarettes.

3. Set-to-Set Variation (σ_S^2) - This variation will be used, in a manner similar to σ_W^2, as a standard against which to compare set-to-set variations in other cigarettes.

Through these estimates the information supplied by the extensive measurements of Monitor cigarettes can be used in the statistical analyses of other cigarettes.

III. MAIN OUTPUT

As explained in Section II the main part of the program consists of analyses of various groups of cigarettes. There is one piece of output for each of these groups. The first part of this section describes the analysis for one such group of cigarettes, the second part explains the rationale behind grouping cigarettes and Section IV covers the flexibility which can be exercised in selecting or changing the groups.

A. Sample Analysis: Marlboro

The main output of the program will be explained by using as an example the analysis for the group of cigarettes consisting of all sizes, packings, and manufacturing locations of Marlboro with a target of 17.5 mg and the basic Marlboro formula. There are ten such "versions" of Marlboro as shown in Table 2.

Table 2

TEN VERSIONS OF MARLBORO

WITH THE SAME TARGET AND FORMULA

Brand	Length & Packing	Manufacturing Location
Marlboro	100 box	Stockton Street
	100 pack	Stockton Street
	100 pack	Manufacturing Center
	100 pack	Louisville
	80 box	Stockton Street
	80 box	Manufacturing Center
	80 box	Louisville
	85 pack	Stockton Street
	85 pack	Manufacturing Center
	85 pack	Louisville

Table 3 shows the program output resulting from the analysis of this group of cigarettes for a thirteen week period.

1. Weekly Averages - This part of the output shows the average, over all ten versions in Table 2, for each of the last thirteen weeks and the average for all thirteen weeks.

2. Tests of Significance - All ten versions of Marlboro had a target of 17.5 mg during the thirteen week period shown in Table 3. Therefore, except for random variation, we should expect all of the tar values to be the same. We can state the following hypotheses:

   a. The averages of all versions over the thirteen weeks are equal.

   b. The averages of all weeks over the ten versions are equal.

   c. The average of the last week is equal to the average of the other twelve weeks.

Table 3: SAMPLE ANALYSIS FOR THE TEN VERSIONS OF MARLBORO IN TABLE 2

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ANALYSIS OF MARBRO FTC TAR
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1.

WEEK	WEEK	WEEK	WEEK	WEEK	WEEK	WEEK	WEEK	WEEK	WEEK	WEEK	WEEK	WEEK	13 WEEK
6 30	7 14	7 21	7 28	8 4	8 11	8 18	8 25	9 1	9 8	9 15	9 22	9 29	AVG
17.27	16.81	16.91	17.12	17.06	16.89	17.25	17.15	17.52	17.61	17.28	16.76	17.24	17.14

2. A. PROB OF OBSRVD DIFF BTWN CIGARETTES= .00010
   B. PROB OF OBSRVD DIFF BTWN WEEKS= .23001
   C. PROB OF OBSRVD DIFF BTWN LAST WK & PREVIOUS 12 WKS= .64815
   D. PROB OF OBSRVD DIFF BTWN LAST WK & TARGET= .21337
   E. PROB OF OBSRVD # OF RUNS IN WEEKLY VALUES= .17500

3. OUTLIER IN LAST WEEK, VERSION 4 100 LV 2.16 1.55

4. SEPARATION OF MEANS

7	80 LV	17.53	1000000000
10	85 LV	17.48	1000000000
9	85 MC	17.46	1000000000
8	85 SS	17.33	1000000000
6	80 MC	17.18	1100000000
5	80 SS	17.18	1100000000
3	100 MC	17.08	1110000000
2	100 SS	16.78	0110000000
4	100 LV	16.75	0110000000
1	100 BSS	16.66	0010000000

d. The average of the last week is equal to 17.5 mg.

e. There are no trends in the weekly averages.

We test a hypothesis by finding the probability of an observed event assuming that the hypothesis is true. If that probability is small (say, .05 or less), we reject the hypothesis.

The program calculates such a probability corresponding to each of the hypotheses listed above. The probabilities are shown in section 2 of Table 3. Hypotheses a. and b. correspond to hypotheses 1. and 2 in Section II. B. and they are tested by using an analysis of variance. For the analysis of Monitor tar the error variation used to test hypotheses 1. and 2. is that which results from the analysis of variance. For the analysis of any other group of cigarettes the error variation used to test hypotheses a. and 6. is that which results from the analysis of variance for that group modified by adding σ_W^2 or σ_S^2 times the appropriate constant. Hypotheses c. and d. are also tested using a modified error variation. Notice that when we test whether the last week is on target, we have an average of ten current tar values rather than an average of four tar values - one, two, three, and four weeks old.

We see from Table 3 that we must reject the hypothesis that all cigarettes (versions) are equal. The other four probabilities are relatively high so we have no reason to doubt the validity of the other four hypotheses.

3. Outliers - If, for the last week, the tar for any version is more than three standard deviations from the value which would be expected for it (based on the previous observations for that version and the average of the other versions for that week), that value will be considered to be an outlier. The identification of the version, its deviation from its expected value, and the value of three standard deviations will be printed out.

4. Separation of Means - If the probability of the observed differences between cigarettes (or versions) in Table 3, part 2.a., is less than .05 there are significant differences between versions of Marlboro (over the thirteen week period), and we can ask which versions are different from which other versions. The "Separation of Means," Table 3, part 4, lists the versions in decreasing order of tar delivery. The ones and zeros to the right of the means indicate where the significant differences are: two versions followed by ones in the same column are not significantly different; two versions not followed by ones in the same column are different at the .05 level of significance.

   If the probability of the observed differences between cigarettes is greater than .05, no separation of means will be shown.

B. Reasons for Grouping Cigarettes

These analyses gain their statistical advantage by using averages (one version averaged over several weeks or one week averaged over several versions). The cost of the advantage in power and responsiveness of the tests is a loss of specificity. The analyses are most appropriate for detecting changes which would affect all cigarettes in a group, simultaneously. For Marlboro these would be such things as changes in the amount or preparation of some component of the blend, the change in paper or filter material affecting all versions, a weight reduction in all versions, etc.

If we are interested, for example, in whether Marlboro 85 at Stockton Street has changed, the analyses above will be little help. However, if we are interested in Marlboro 85 at Stockton Street because we suspect all Stockton Street production, we can simply designate "all cigarettes made at Stockton Street" as one of the groups to be analyzed. This will produce more reliable results than looking individually at each type of cigarette made at Stockton Street.

IV. PROGRAM FLEXIBILITY

Under routine operation the only input the program will require is the sixteen cards described in Section I. However, there are several situations which can occur which will require changes in the set of control cards. These changes are discussed below.

A. Changes in the Monitor Series

It is apparent from Sections II and III that the program analyses depend heavily on the assumption that all Monitors come from a common source. During any thirteen week period in which Monitors from two different series were used as controls, the assumption may not hold. The program will automatically adjust the Monitor tar values from one series to have the same average as those from the other series. This adjustment will be made when one number on one control card is changed to show that the number of weeks of the older Monitor series is not equal to thirteen. The Monitor tar values for the Monitor series appearing the fewest weeks will be adjusted.

B. Choice of Groups of Cigarettes to be Analyzed

We have discussed the analysis for the group of cigarettes consisting of all versions of Marlboro with the same target tar. A similar analysis can be performed for any desired group of cigarettes and for any number of such groups. Only three control cards have to be changed or added to change or add a group. If the cigarettes in a group do not all have the same target tar, a target for the average can be found by averaging the target for each cigarette in the group. However, the first hypothesis tested in part 2 of Table 3 will be meaningless as will be the separation of means. These two parts of the analysis deal with differences between cigarettes in a group. There should be significant differences if the cigarettes have different targets.

The analysis for a group of cigarettes will be more powerful if more cigarettes are included. However, more cigarettes should not be included at the sacrifice of having some common characteristic for all of the cigarettes in a group.

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